CLAIMS

We claim:

1. A fuel cell system, comprising:

a fuel cell including at least one anode; and

a fuel supply apparatus that supplies a plurality of fuel droplets to the at least one anode.

2. A fuel cell system as claimed in claim 1, further comprising:

a controller adapted to monitor a rate of fuel consumption at the at least one anode and to control the fuel supply apparatus to supply droplets at a rate corresponding to the rate of fuel consumption.

3. A fuel cell system as claimed in claim 1, wherein the fuel cell comprises at least one anode pair, the anodes within the at least one anode pair face one another and define a fuel passage therebetween, and the fuel supply apparatus directs the fuel droplets into the fuel passage.

4. A fuel cell system as claimed in claim 1, wherein the fuel supply apparatus comprises a thermal drop ejector.

5. A fuel cell system as claimed in claim 1, wherein the fuel supply apparatus comprises a piezoelectric drop ejector.

6. A fuel cell system as claimed in claim 1, wherein the fuel supply apparatus comprises a flextensional drop ejector.

7. A fuel cell system as claimed in claim 1, wherein the fuel supply apparatus comprises an ultrasonic atomizer.

8. A fuel cell system, comprising:

a fuel cell including at least one anode; and

fuel supply means for supplying a plurality of droplets to the at least one anode.

9. A fuel cell system as claimed in claim 8, further comprising:

storage means for storing energy generated with fuel that is on the at least one anode when the system is shut down.

10. A fuel cell system, comprising:

a fuel cell including at least one anode; and

fuel supply means for reducing fuel crossover by supplying a plurality of droplets to the at least one anode at a rate corresponding to fuel consumption at the at one anode.

11. A fuel cell system, comprising:

a fuel cell stack including

a plurality of anodes pairs arranged such that the anodes within each anode pair face one another and define a fuel passage therebetween, and

a plurality of cathodes; and

a fuel reservoir;

a fuel supply apparatus that draws fuel from the fuel reservoir and supplies a plurality of fuel droplets to the fuel passages.

12. A fuel cell system as claimed in claim 11, wherein the fuel supply apparatus comprises at least one of a thermal drop ejector, a piezoelectric drop ejector, a flextensional drop ejector, and an ultrasonic atomizer.

13. A fuel cell system as claimed in claim 11, further comprising:

a controller adapted to monitor a rate of fuel consumption at the anodes and to control the fuel supply apparatus to supply droplets at a rate corresponding to the rate of fuel consumption.

14. A method of operating a fuel cell having an anode, the method comprising the steps of:

directing a spray of fuel droplets onto the anode; and

consuming the fuel at the anode.

15. A method as claimed in claim 14, wherein the step of directing a spray of fuel droplets onto the anode comprises creating the spray of fuel droplets with at least one of a thermal drop ejector, a piezoelectric drop ejector, a flextensional drop ejector, and an ultrasonic atomizer.

16. A method as claimed in claim 14, wherein the step of directing a spray of fuel droplets onto the anode comprises the steps of:

generating a spray of fuel droplets; and

blowing the droplets towards the anode with a fan.

17. A method as claimed in claim 14, wherein the step of directing a spray of fuel droplets onto the anode comprises directing a spray of fuel droplets onto the anode at a rate corresponding to a rate at which the fuel is being consumed at the anode.

18. A fuel supply system for use with a fuel cell including an anode, comprising:

a fuel reservoir that stores fuel; and

fuel supply means, operably connected to the fuel reservoir, for supplying a plurality of droplets to the at least one anode.

19. A fuel supply system as claimed in claim 18, further comprising:

a controller adapted to monitor a rate of fuel consumption at the anode and to control the fuel supply means to supply droplets at a rate corresponding to the rate of fuel consumption.

20. A fuel supply system as claimed in claim 18, further comprising:

a controller adapted to monitor a rate of fuel consumption at the anode and to control the fuel supply means to supply droplets at a rate that results in a fuel layer being maintained on the anode.

21. A drop generator, comprising:

a housing including a liquid reservoir;

an orifice plate, associated with the housing, including a plurality of orifices; and

a vibrating element, associated with the housing, positioned a predetermined distance from the orifice plate such that the orifice plate and vibrating element define an open region therebetween in fluid communication with the fuel reservoir;

wherein the predetermined distance is such that a capillary force sufficient to draw liquid from the liquid reservoir is created in the open region.

22. A drop generator as claimed in claim 21, wherein the vibrating element comprises a piezoelectric vibrating element.

23. A drop generator as claimed in claim 21, wherein the vibrating element defines a perimeter, the housing defines an interior surface, and a passage from the liquid reservoir to the open region is located between a portion of the perimeter of the vibrating element and the interior surface of the housing.

24. A drop generator, comprising:

a housing including a liquid reservoir;

an orifice plate, associated with the housing, including a plurality of orifices;

a vibrating element, associated with the housing, positioned adjacent to the orifice plate; and

a vibrating element tray positioned within the housing between the vibrating element and the liquid reservoir.

25. A drop generator as claimed in claim 24, wherein the vibrating element comprises a piezoelectric vibrating element.

26. A drop generator as claimed in claim 24, wherein the vibrating element defines a first surface that faces the orifice plate and a second surface opposite the first surface and the vibrating element tray defines an open region adjacent to the second surface of the vibrating element.

27. A drop generator, comprising:

a housing defining a liquid reservoir;

an orifice plate, associated with the housing, including a plurality of orifices;

a vibrating element, associated with the housing, positioned a predetermined distance from the orifice plate such that the orifice plate and vibrating element define an open region therebetween in fluid communication with the fuel reservoir, the predetermined distance being such that a capillary force sufficient to draw liquid from the liquid reservoir is created in the open region; and

a vibrating element tray positioned within the housing between the vibrating element and the liquid reservoir.

28. A drop generator as claimed in claim 27, wherein the vibrating element comprises a piezoelectric vibrating element.

29. A drop generator as claimed in claim 27, wherein the vibrating element defines a perimeter, the housing defines an interior surface, and a passage from the liquid reservoir to the open region is located between a portion of the perimeter of the vibrating element and the interior surface of the housing.

30. A drop generator as claimed in claim 27, wherein the vibrating element defines a first surface that faces the orifice plate and a second surface opposite the first surface and the vibrating element tray defines an open region adjacent to the second surface of the vibrating element.

31. A drop ejector, comprising:

a fluid reservoir;

a flexible metal membrane defining an orifice associated with the fluid reservoir; and

a layer of conductive material positioned in spaced relation to the flexible metal membrane such that the flexible metal membrane will oscillate in response to the application of an excitation signal between the flexible metal membrane and the layer of conductive material.

32. A drop ejector as claimed in claim 31, further comprising:

a layer of piezoelectric material between the flexible metal membrane and the layer of conductive material.

33. A drop ejector as claimed in claim 32, wherein the piezoelectric material is in contact with the flexible metal membrane.

34. A drop ejector as claimed in claim 31, wherein the flexible metal membrane includes a surface that defines a portion of the reservoir.

35. A drop ejector as claimed in claim 31, wherein the orifice comprises a nozzle.

36. A method of manufacturing a drop ejector, comprising the steps of:

forming a fluidic chamber subassembly;

forming a flextensional orifice plate subassembly; and

attaching the fluidic chamber subassembly and the flextensional orifice plate subassembly to one another.

37. A method as claimed in claim 36, wherein the step of forming a fluidic chamber subassembly comprises the steps of:

forming a photosensitive layer on a substrate;

removing portions of the photosensitive layer; and

forming an aperture that extends through the substrate by one of a mechanical ablation process and a thermal ablation process.

38. A method as claimed in claim 36, wherein the step of forming a flextensional orifice plate subassembly comprises the steps of:

forming a flexible metal membrane having an orifice on a mandrel;

forming a piezo layer on the flexible metal membrane; and

forming a metal layer on the piezo layer.

39. A method as claimed in claim 38, wherein the step of attaching the fluidic chamber subassembly and the flextensional orifice plate subassembly to one another comprises the steps of:

removing the flextensional orifice plate subassembly from the mandrel; and

laminating the flextensional orifice plate subassembly onto the fluidic chamber subassembly.

40. A flextensional drop ejector formed by a process including the steps of:

forming a fluidic chamber subassembly;

forming a flextensional orifice plate subassembly; and

attaching the fluidic chamber subassembly and the flextensional orifice plate subassembly to one another.

41. A flextensional drop ejector as claimed in claim 40, wherein the step of forming a fluidic chamber subassembly comprises the steps of:

forming a photosensitive layer on a substrate;

removing portions of the photosensitive layer; and

forming an aperture that extends through the substrate by one of a mechanical ablation process and a thermal ablation process.

42. A flextensional drop ejector as claimed in claim 40, wherein the step of forming a flextensional orifice plate subassembly comprises the steps of:

forming a flexible metal membrane having an orifice on a mandrel;

forming a piezo layer on the flexible metal membrane; and
forming a metal layer on the piezo layer.

43. A flextensional drop ejector as claimed in claim 42, wherein the step of attaching the fluidic chamber subassembly and the flextensional orifice plate subassembly to one another comprises the steps of:

removing the flextensional orifice plate subassembly from the mandrel; and

laminating the flextensional orifice plate subassembly onto the fluidic chamber subassembly.

44. A method of manufacturing a drop ejector, comprising the steps of:

forming a boundary layer defining an ejection chamber on a substrate;

forming a sacrificial layer within the ejection chamber;

forming a flexible membrane having an orifice over the boundary layer and the sacrificial layer; and

removing the sacrificial layer from within the ejection chamber.

45. A method as claimed in claim 44, wherein the step of forming a boundary layer defining an ejection chamber on a substrate comprises forming an annular boundary layer defining an ejection chamber on a substrate.

46. A method as claimed in claim 44, wherein the step of forming a boundary layer defining an ejection chamber on a substrate comprises forming silicon dioxide boundary layer defining an ejection chamber on a substrate.

47. A method as claimed in claim 44, wherein the step of forming a sacrificial layer within the ejection chamber comprises forming polysilicon sacrificial layer within the ejection chamber.

48. A method as claimed in claim 44, wherein the step of forming a flexible membrane having an orifice over the boundary layer and the sacrificial layer comprises

forming a flexible metal membrane having an orifice over the boundary layer and the sacrificial layer.

49. A method as claimed in claim 48, further comprising the step of:

forming a metal layer in spaced relation to the flexible metal membrane.

50. A method as claimed in claim 44, wherein the step of removing the sacrificial layer from within the ejection chamber comprises removing the sacrificial layer from within the ejection chamber by a wet etching process.

51. A method as claimed in claim 44, wherein the step of removing the sacrificial layer from within the ejection chamber comprises the steps of:

forming a bore though the substrate; and

removing the sacrificial layer from within the ejection chamber by a wet etching process performed through the bore.

52. A method of manufacturing a drop ejector, comprising the steps of:

forming an annular boundary layer on a substrate from a predetermined material, the boundary layer defining an ejection chamber;

forming a sacrificial layer within the ejection chamber and around the annular boundary layer;

polishing the sacrificial layer until the sacrificial layer and annular boundary layer define a common plane;

forming a flexible membrane having a nozzle over the common plane;

forming a bore through substrate to the sacrificial layer; and

removing the sacrificial layer from within the ejection chamber by a process performed through the bore that will not substantially chemically effect the predetermined material that forms the annular boundary layer.

53. A method as claimed in claim 52, wherein the step of forming a sacrificial layer within the ejection chamber and around the annular boundary layer comprises forming

polysilicon sacrificial layer within the ejection chamber and around the annular boundary layer.

54. A method as claimed in claim 52, wherein the step of forming a flexible membrane having a nozzle over the common plane comprises forming a flexible metal membrane having a nozzle over the common plane.

55. A method as claimed in claim 52, wherein the step of forming a bore through substrate to the sacrificial layer comprises forming a bore through substrate to the sacrificial layer with a dry etching process.

56. A method as claimed in claim 52, wherein the step of removing the sacrificial layer from within the ejection chamber by a process performed through the bore comprises removing the sacrificial layer from within the ejection chamber by a wet etching process performed through the bore.

57. A method as claimed in claim 52, further comprising the step of:
forming a metal layer in spaced relation to the flexible metal membrane.

58. A drop ejector formed by a process, comprising the steps of:
forming a boundary layer defining an ejection chamber on a substrate;
forming a sacrificial layer within the ejection chamber;
forming a flexible membrane having an orifice over the boundary layer and the sacrificial layer; and
removing the sacrificial layer from within the ejection chamber.

59. A drop ejector as claimed in claim 58, wherein the step of forming a boundary layer defining an ejection chamber on a substrate comprises forming an annular silicon dioxide boundary layer defining an ejection chamber on a substrate.

60. A drop ejector as claimed in claim 58, wherein the step of forming a sacrificial layer within the ejection chamber comprises forming polysilicon sacrificial layer within the ejection chamber.

61. A drop ejector as claimed in claim 58, wherein the step of forming a flexible membrane having an orifice over the boundary layer and the sacrificial layer comprises forming a flexible metal membrane having an orifice over the boundary layer and the sacrificial layer.

62. A drop ejector as claimed in claim 61, further comprising the step of:

forming a metal layer in spaced relation to the flexible metal membrane.

63. A drop ejector as claimed in claim 58, wherein the step of removing the sacrificial layer from within the ejection chamber comprises removing the sacrificial layer from within the ejection chamber by a wet etching process.

64. A drop ejector as claimed in claim 58, wherein the step of removing the sacrificial layer from within the ejection chamber comprises the steps of:

forming a bore though the substrate; and

removing the sacrificial layer from within the ejection chamber by a wet etching process performed through the bore.

65. A drop ejector, comprising:

a substrate defining first and second sides;

an ejection chamber layer, associated with the first side of the substrate, including a boundary portion formed from a first material and having an inner surface defining an ejection chamber and an outer surface, and a second portion associated with the outer surface of the boundary portion formed from a second material, the second material being a different material than the first material; and

a flexible membrane having an orifice over the ejection chamber layer.

66. A drop ejector as claimed in claim 65, wherein the substrate defines a bore that extends from the second side to the ejection chamber.

67. A drop ejector as claimed in claim 65, wherein the substrate comprises an silicon wafer.

68. A drop ejector as claimed in claim 65, wherein the boundary portion comprises an annular boundary portion.

69. A drop ejector as claimed in claim 65, wherein the first material comprises silicon dioxide.

70. A drop ejector as claimed in claim 65, wherein the second material comprises polysilicon.

71. A drop ejector as claimed in claim 65, wherein the flexible membrane comprises a flexible metal membrane.

72. A drop ejector as claimed in claim 71, further comprising:

a layer of conductive material positioned in spaced relation to the flexible metal membrane such that the flexible metal membrane will oscillate in response to the application of an excitation signal between the flexible metal membrane and the layer of conductive material.

73. A method of forming a drop ejector, comprising the steps of:

providing a substrate defining first and second sides;

forming an ejection chamber on the first side of the substrate;

forming an aperture, which extends from the first side to the second side of the substrate and is operably connected to the ejection chamber, by one of a mechanical ablation process and a thermal ablation process; and

covering the ejection chamber with a flexible membrane having an orifice.

74. A method as claimed in claim 73, wherein the step of forming an ejection chamber on the first side of the substrate comprises forming a pair of connection chambers and a channel therebetween on the first side of the substrate.

75. A method as claimed in claim 73, wherein the step of covering the ejection chamber with a flexible membrane having an orifice comprises the steps of:

forming a flextensional orifice plate subassembly on a mandrel;

removing the flextensional orifice plate subassembly from the mandrel; and

laminating the flextensional orifice plate subassembly onto the substrate over the ejection chamber.

76. A drop ejector formed by a method comprising the steps of:

providing a substrate defining first and second sides;

forming an ejection chamber on the first side of the substrate;

forming an aperture, which extends from the first side to the second side of the substrate and is operably connected to the ejection chamber, by one of a mechanical ablation process and a thermal ablation process; and

covering the ejection chamber with a flexible membrane having an orifice.

77. A drop ejector as claimed in claim 76, wherein the step of forming an ejection chamber on the first side of the substrate comprises forming a pair of connection chambers and a channel therebetween on the first side of the substrate.

78. A drop ejector as claimed in claim 76, wherein the step of covering the ejection chamber with a flexible membrane having an orifice comprises the steps of:

forming a flextensional orifice plate subassembly on a mandrel;

removing the flextensional orifice plate subassembly from the mandrel; and

laminating the flextensional orifice plate subassembly onto the substrate over the ejection chamber.

79. A drop ejector, comprising:

a substrate defining first and second sides formed from at least one of a glass material and ceramic material;

an ejection chamber in the first side of the substrate;

an aperture, extending from the first side to the second side of the substrate, operably connected to the ejection chamber; and

a flexible membrane having an orifice covering the ejection chamber.

80. A drop ejector as claimed in claim 79, further comprising:

a pair of conductive layers associated with the flexible membrane and a piezo layer between the metal layers.

81. A drop ejector as claimed in claim 79, wherein the flexible membrane comprise a flexible metal membrane, the drop ejector further comprising:

a layer of conductive material positioned in spaced relation to the flexible metal membrane such that the flexible metal membrane will oscillate in response to the application of an excitation signal between the flexible metal membrane and the layer of conductive material.